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Occurrence of *Staphylococcus aureus* in and the Moisture Content of Precooked Canned Bacon

EDMUND M. POWERS*, THOMAS G. LATT, DOUGLAS R. JOHNSON and D. B. ROWLEY

Food Sciences Laboratory
U.S. Army Natick Research and Development Command
Natick, Massachusetts 01760

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ABSTRACT

Staphylococcus aureus was found in 9.0% of 221 cans of precooked bacon. The count in 6.9% of the cans exceeded 1000/g and ranged as high as 1.7×10^5/g. Aerobic plate counts were greater than 10^5/g in 24% of the cans. The maximum moisture to salt ratio (percent moisture divided by percent salt) of 9.0, permitted by Federal Specifications, was exceeded in 73.0% of the cans and ranged from 5.97 to 21.44. This bacon production was rejected for military procurement.

Precooked Canned Bacon offers several advantages as a military subsistence item, not the least of which are stability without refrigeration and reduced weight. It is, however, a product which must be carefully processed and controlled, since it is not sterile and depends on low water activity for its stability.

Military Specifications (*12*) require a mean moisture-to-salt ratio (percent moisture divided by percent salt) of 9.0 or less to help assure the safety of Precooked Canned Bacon without refrigeration. This requirement was based on an empirical study of precooked canned bacon made by Whiting et al. (*13*) which showed that for military prefried canned bacon a brine ratio of approximately 9.0 corresponded to a moisture/salt × protein index of 0.400. This index (0.400) corresponded to a water activity below the point (0.9) at which *S. aureus* could grow anaerobically and would undoubtedly provide better assurance of microbiological safety than a moisture to salt ratio. However, because the cost of an additional protein analysis was considered to be prohibitive, a moisture to salt ratio requirement, only, was selected. Ultimately, a maximum water activity should be specified to assure microbiological safety of precooked canned bacon.

If water activity is not controlled, *S. aureus* is capable of growing and producing enterotoxin in bacon packed under vacuum (*3, 5, 6, 9, 10*) and will grow anaerobically at a water activity of 0.90 (*8, 13*). With sufficient time (30 days at 30C) the organism will also grow aerobically at a water activity as low as 0.86 (*8, 13*). Therefore, the water activity of precooked canned bacon should be strictly controlled to prevent growth of bacterial pathogens, particularly *S. aureus*, which may be introduced, since the bacon in question was hand-packed into cans after cooking and received no further heat treatment.

The following study of precooked canned bacon (*12*), produced for the United States Army, pointed out some potential problems. In this particular production, for example, the average moisture-to-salt ratio, lot value, ranged from 9.55 to as high as 18.7, for 12 lots tested by both a private laboratory and a Government Laboratory. The lot value must be 9.0 or less for a lot to be accepted. Since every lot tested failed to meet this requirement, the U. S. Army Research and Development Command (NARADCOM) agreed to analyze the bacon to confirm the findings of the other two laboratories and to determine if the product was microbiologically hazardous.

MATERIALS AND METHODS

Bacon

Sliced, precooked bacon, in No. 2½ cans was commercially produced for the United States Army in accordance with Military Specification MIL-B-35032C, as amended (*12*). Two hundred and twenty-one cans, comprised of 13 cans from each of 17 lots, each containing 22 oz. of bacon, were analyzed. The cans had been stored at ambient temperatures for 3 to 6 months before testing, and all appeared to be normal and in excellent condition. Vacuum of each can was determined with a Budenberg Vacuum Gauge (Broadheath, Nr. Manchester, England).

Chemical analyses

Moisture and salt determination. Procedures of the Association of Official Analytical Chemists (Chapter 24, Meat and Meat Products) were used for determination of percent moisture and percent salt (*2*).

Moisture-to-salt ratio. The moisture-to-salt ratio of each sample was determined by dividing the percent moisture by the percent salt. A lot of bacon was acceptable only when the 99% confidence interval of a single tailed "t" test fell below 9.0 for the lot average. This method was based upon 13 samples for each lot. The "t" factor for T_{99} and 12 degrees of freedom was determined from a Table of Percentiles of the "t" distribution and multiplied by the standard deviation of 13 samples. This product, added to the mean moisture-to-salt ratio of the 13 samples, must be below 9.0 for the lot to be acceptable when all other requirements are satisfied. Under these conditions no more than 1% of the lots accepted will have a M/S ratio greater than 9.0.

Water activity measurement. Sample jars containing 100 g of bacon were held at room temperature overnight to allow the bacon within the jar to come into moisture equilibrium with the head space atmosphere of the jar. Measurement of water activity (a_w) was then made, within a constant temperature chamber (24 C) with an EG&G Model 880 Dew Point Hygrometer (Environmental Equipment Division, Waltham, MA). Ambient (sample) temperature measurements were made by inserting a thermometer into the sample jar. Air was circulated within the closed system at the rate of 1.6 CFH and the hygrometer was allowed to come into equilibrium with the water vapor of the head space before dew point temperature readings were made. Dew point and ambient temperature readings were converted to corresponding water vapor from appropriate tables. Water activity of the bacon was calculated by dividing the dew point vapor pressure by the vapor pressure of pure water at the sample (ambient) temperature. The hygrometer was frequently checked against standard NaCl and $ZnSo_4$ solutions of known water activities with readings within +2% a_w of the solution value being the basis for acceptability.

Microbiological analyses

Sample preparation. Bacon was aseptically removed from each can and laid on a sterile surface inside of a class 100 laminar flow clean bench. A 50-g amount of bacon, obtained by cutting strips from the ends and the middle of the slab, was aseptically transferred to a sterile blender jar and blended in 450 ml of Butterfield's (*1, 11*) sterile buffered water (SBW) for 2 min. This slurry constituted a 1:10 dilution. Appropriate tenfold serial dilutions were made by transferring 10 ml into 90 ml of SBW.

Media. All media were purchased from Difco Laboratories, Detroit, Michigan.

Aerobic plate count. One milliliter of dilutions ranging from 10^{-2} to 10^{-4} was pipetted into duplicate petri plates, and poured with Plate Count Agar. Plates were incubated at 35C and counted after 48 h.

Yeast and mold count. One milliliter of 10^{-2} and 10^{-3} dilutions was pipetted into duplicate petri plates, and poured with potato dextrose agar acidified to pH 3.5. Plates were incubated at 23 C for 5 days before counting.

Staphylococcus aureus. A surface plating procedure (*1*) was used by distributing 1 ml of 1:100 dilution equitably (i.e.; 0.4 ml, 0.3 ml, 0.3 ml) over triplicate plates of Baird-Parker agar. The agar plates were previously prepared and dried by overnight incubation at 35 C. The inoculum was spread over the surface of the agar with sterile, bent glass streaking rods. Plates were incubated at 35 C and examined after 24 and 48 h for typical, black, shiny, convex colonies, surrounded by a clear zone (*1,2*). Typical colonies were tested for coagulase production (*1,2*).

RESULTS

Table 1 shows the distribution of microbial counts in 221 cans of precooked bacon analyzed. The aerobic plate count (APC) ranged from <100 (6.3%) to 3.5×10^7/g (1.4%). Seventy percent of the cans had APC's ranging from 10^2 to 10^5/g, but 24% had APCs greater than 10^5/g. *S. aureus* was found in 9.0% of the cans and counts in 6.9% of the cans were greater than 1000/g, ranging as high as 1.7×10^5/g. No yeasts or molds were detected at 1:100, or greater dilution.

TABLE 1. *Distribution of microbiological counts in Precooked Canned Bacon. (Percent of samples with various counts/grams[a].)*

Organism	100	101-1000	1001-10,000	10,0001 to 100,000	100,0001 to 1,000,000	1,000,001 to 10,000,000	> 10,000,000
Aerobic plate count	6.3	22.2	23.0	25.0	14.0	8.6	1.4[b]
S. aureus	90.9	2.3	3.2	2.3	1.4[c]	0	0
Yeast and mold	100	0	0	0	0	0	0

[a]Total number of cans sampled was 221.
[b]Highest APC obtained was 3.5×10^7/g.
[c]Highest *S. aureus* count was 1.7×10^5/g.

TABLE 2. *Bacterial counts, water activity (a_w), moisture/salt ratio and percent salt in cans containing coagulase positive staphylococci.*

Can No.	APC/g	Staphylococci/g	a_w	Moisture/[a] salt ratio	Percent salt
1	1.7×10^3	2×10^2	0.86	12.26	2.88
2	3.2×10^5	1×10^5	0.87	14.57	2.38
3	2.6×10^6	1.7×10^4	0.88	10.04	3.41
4	3.5×10^7	9.4×10^3	0.89	10.43	3.09
5	4.5×10^6	8.4×10^4	0.89	9.60	3.10
6	4×10^5	4×10^2	0.90	10.95	2.81
7	4.7×10^4	1.9×10^4	0.90	10.37	3.11
8	1.1×10^5	5.2×10^4	0.90	10.89	2.61
9	7×10^5	2.7×10^3	0.91	9.97	3.15
10	2.2×10^5	7×10^2	0.92	8.73	3.17
11	2.7×10^6	5×10^2	0.93	14.76	2.34
12	3.4×10^5	7.1×10^3	0.93	10.95	3.10
13	1.2×10^6	2.3×10^3	0.94	18.09	2.39
14	8.7×10^4	9.5×10^3	0.94	13.33	2.58
15	3.2×10^4	2×10^3	0.95	10.72	3.19
16	9×10^6	2.3×10^3	0.95	12.67	2.83
17	1×10^6	2.5×10^4	0.95	11.02	2.82
18	4×10^5	1.4×10^5	0.95	12.44	2.71
19	3×10^4	1×10^2	0.96	9.58	3.11
20	2.6×10^6	1.7×10^5	0.96	21.44	2.14

[a]Percent moisture divided by percent salt.

Table 2 shows the water activity, moisture/salt ratio, percent salt, and microbiological counts in the 20 cans in which *S. aureus* was found. No apparent relationship between any of these parameters was demonstrated since high counts were found in samples with both low (0.87) and high (0.96) water activity. Conversely, low counts were also found at both extremes of water activity. The water activity varied considerably in these and, indeed, in all cans produced and analyzed. There was great variation in the moisture/salt ratio in the 20 cans shown, which was typical of all cans tested, and which had no apparent relationship with bacterial counts, or with water activity. All of these cans, with one exception, and most (73.0%) of the 221 cans tested exceeded the maximum moisture/salt ratio of 9.0 permitted (*12*). Salt concentration varied between 2 and 3%. The vacuum pressure in 67% of the cans was 20 inches or greater as required by the specification and all cans had a vacuum.

DISCUSSION

Whiting et al. (*13*) suggested three criteria for predicting the spoilage potential of precooked canned bacon stored without refrigeration, which are listed as follows in order of importance: (*a*) a moisture divided by salt times protein index of 0.400, or less; (*b*) a brine ratio (moisture divided by salt) of 9.0, or less; and (*c*) a salt concentration of 1.7% or higher (*13*). Precooked canned bacon which met these three conditions was considered to have a water activity low enough (0.90 - 0.91) to inhibit growth of pathogenic bacteria, with the possible exception of *S. aureus* under aerobic conditions (*13*). Scott (*8*) reported that under aerobic conditions *S. aureus* had a limiting water activity for growth of 0.86 whereas under anaerobic conditions the limiting water activity was 0.90.

Failure of the bacon tested in this study to meet the second requirement; i.e., a moisture/salt ratio of 9.0, as required by Military Specification MIL-B-35032C (*12*), confirmed the findings of two other independent laboratories, and was the primary basis for rejection of the bacon by the Army. The poor microbiological quality (APC greater than 10^5/g) of nearly one-fourth of the cans tested (Table 1) and the presence of *S. aureus* in 9.0% of the cans, together with wide variations in both water activity and moisture/salt ratio, demonstrated the potentially hazardous nature of this product and supported the decision to reject the bacon. The *S. aureus* found could have been remnants of an even higher population which was destroyed by cooking and which could have produced enterotoxin before being cooked. They could also represent a growing population in the cans which would eventually reach sufficient numbers during storage, to produce enough enterotoxin to cause food poisoning symptoms. As reported by Thatcher (*9*), staphylococcal toxin is not completely destroyed unless the bacon is cooked to a crisp condition (205C for 12 min).

The fact that there was no physical indication of spoilage, or of bacterial growth in the canned bacon examined, was not sufficient assurance of its safety, since it has previously been reported (*9*) that under anaerobic conditions, bacon was acceptable as food even though staphylococci grew and produced enterotoxin. McCoy and Faber (*7*) alluded to this same phenomenon in other meats. Under aerobic conditions, however, the same bacon had a offensive odor and was obviously spoiled.

Although no case of food poisoning attributable to bacon has been reported in the literature (*4*), several investigators have reported both growth (*3, 5, 6, 9, 10*) and enterotoxin production (*9*) by staphylococci in uncooked Canadian and Wiltshire bacon under vacuum, and in anaerobic packs, at temperatures between 20 and 37 C. The likelihood of this happening in low salt (3% or less) precooked bacon is even greater since the spoilage, or indigenous microflora, will be destroyed, or partially reduced by cooking. Staphylococci introduced by human handlings, or from dirty equipment during the packing process, will have little or no competition and could grow quite well if the three conditions above are not met. It was shown that *S. aureus* was able to grow, and successfully compete with the indigenous microflora in uncooked bacon stored under anaerobic conditions at 25 C, and did so more rapidly, and attained greater numbers when the spoilage flora was first "decimated" by irradiation (*5, 6*).

This report and the literature cited clearly indicate the potentially hazardous nature of this nonsterile, precooked, vacuum-canned bacon, stored without refrigeration and further emphasizes the need for well-controlled manufacturing procedures during production. The presence of *S. aureus* usually indicates contamination from the skin, mouth, or nose of workers, or from dirty equipment. Presence of large numbers of staphylococci is generally a good indication of inadequate sanitation and temperature control. Since the bacon studied is hand-packed into cans after cooking and can easily become contaminated with staphylococci, it is extremely important to observe hygienic procedures, good manufacturing practices, cooking and low moisture-to-salt ratio, in particular, are met to produce a safe and stable product.

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